S E N S 2 0 0 7
Third Scientific Conference with International Participation
SPACE, ECOLOGY, NANOTECHNOLOGY, SAFETY
27–29 June 2007, Varna, Bulgaria

EARTHQUAKE MONITORING IN PROVADIA REGION

Emil Botev, Sonya Dimitrova, Irena Tzoncheva

Geophysical Institute – Bulgarian Academy of Sciences
e-mail: ebotev@geophys.bas.bg

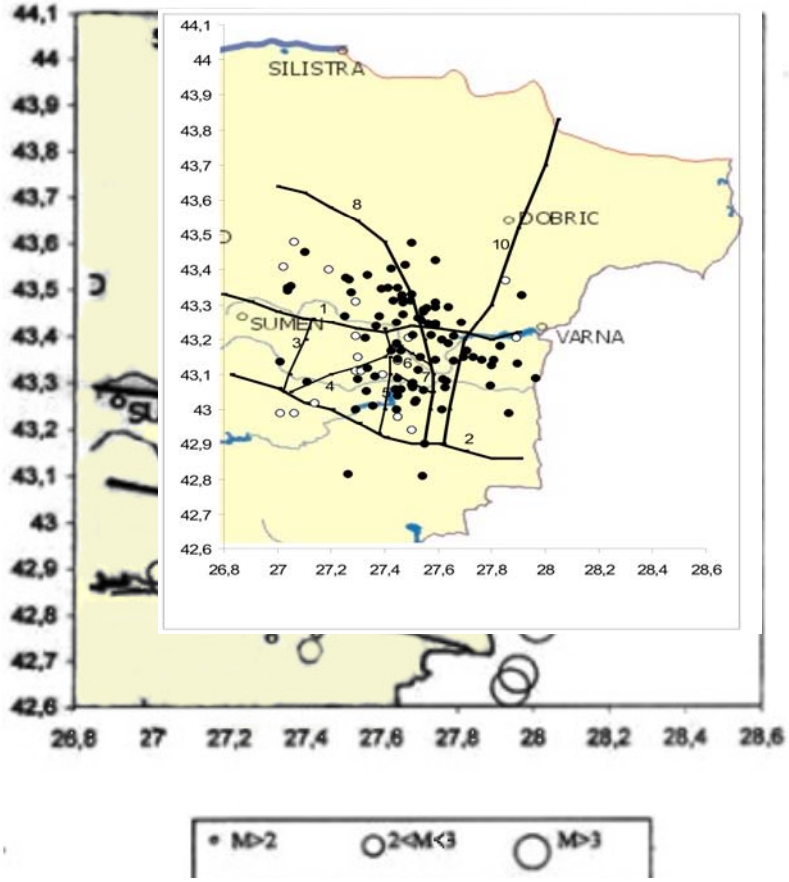
Key words: *Earthquake monitoring, Induced seismicity*

Abstract: *The Provadia region is remarkable with the exploitation of the biggest salt deposit body in Bulgaria. After the increasing of the felt events during the last years some public opinions about the induced character of the seismicity appear. This paper presents an outloock of the seismicity before and after the Local Seismic Network (LSN) construction in the Provadia region. A more detailed analysis of the space and time distributions of the earthquakes in the investigated region is made for the period of high sensitive LSN registrations (after1995). Some general conclusions about the character of the seismicity around the Mirovo salt body (central part of the Provadia region) are proposed. The biggest number of events in the depth interval 0-5 km might be associated with some influence of the salt body exploitation. From the magnitude-depth and –time distributions is obtained that the depth interval of the strongest earthquakes is between 8 and 20 km and they are followed by classical (tectonic type) aftershock series. On these reasons it could be supposed that the strongest earthquakes in Provadia region are not directly induced events. The abrupt increasing of the number of felt earthquakes for the last 30 years and their hypicentral distribution around the Mirovo salt body does not allow to exclude the indirect influence of it's exploitation - like triggering of some tectonic seismic events, for example.*

The work gives some generalized information about the seismic events in the Provadia region ($\lambda = 27^0$ -28^0 E and $\varphi = 42.6^0 – 43.6^0$ N) recorded by the seismological network of Bulgaria (NOTSSI) for the period 1980-2005. Special emphasize on the seismicity of the region during the operation of the Provadia Local Seismic Network (LSN) is made (1995-2005). The recording and space localization of the seismic events in NOTSSI is realized by means of 14 permanent stations all over the country and 7 local stations belonging to 2 networks. The Provadia LSN consists of 5 stations. The sensitivity of the seismographs allows recording and processing of a big number of the weak earthquakes with M > 1.0. The precision of determining the epicentral location is different and it depends first of all on the specific position of the epicentre towards the geometry of the recording national and local networks.

The region of Provadia is not very dangerous seismic zone (Bonchev et al.,1982), but it is remarkable with the Mirovo salt deposit body and the created public opinion, that the local moderate seismicity is induced by the method of exploitation of the salt body. In fact the historical analysis of the earthquake catalogues (Grigorova et al., 1979; Christoskov et al., 1979, Solakov & Simeonova, 1993; Botev et al., 1993-2004) shows an abrupt increasing of the stronger events (as a rule with magnitude M>3.0) for the last 30 years – about 45 earthquakes versus only 5 for the period before 1976. This level of the present moderate seismic activity of the Provadia region is comparable to the same one for the most active seismic zones in Bulgaria well known with catastrophic earthquakes in the past.

Provadia region is situated in the South Moesian periplatform (transition) zone between the Moesian platform and East Fore-Balkans folded zone. The main fault lineament (first order structures) are: 1.South Moesian; 2.North Fore-Balkans; 8.Sindel-Vetren; 10.Venelin-Dobrich (Fig.1). The second order fault structure around Provadia depression are: 5. Provadiiski; 6. Padinski; 7. Sultamski and 4. Hrabrovski to the West (Mihajlov et al., 1994). With empty circles are noted the epicenters before the NOTSSI operation, with black ones – during the operation of NOTSSI (after 1980), but before the starting of the Local Seismic Network in Provadia (1995). The epicenters distribution marks some correlation with Sindel-Vetren fault lineament, especially for the events before the NOTSSI operation, which are predominately macroseismologically determined.



g

S (N1) and Sindel-
Vetren fter the NOTSSI
construc of lack of nearby
situated

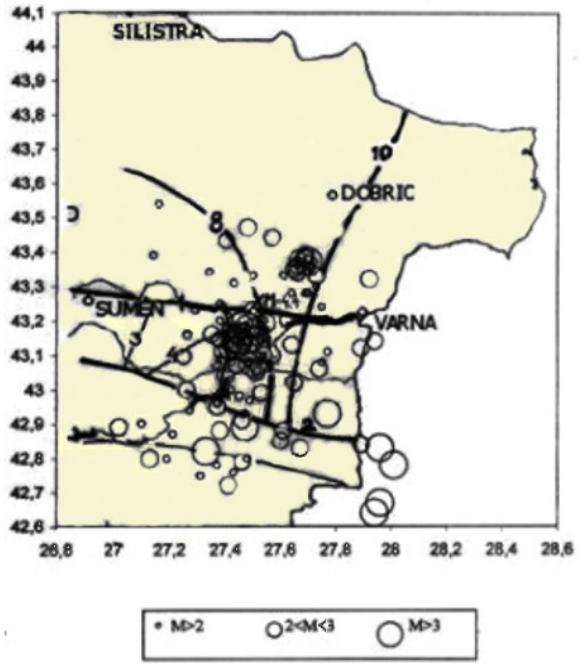


Fig.2. *Map of epicentres in the region after the Provadia LSN constructing (1995-2003)*

For the next 9-years period of high sensitive LSN observations (1995-2003) the data about more than 360 seismic events with M>0.5 on the territory of the Provadia region are used. Relatively low seismic activity is observed - only 128 earthquakes are successfully localized for this period. The seismicity map (Fig. 2) shows better the active strip with NE-SW oriented epicentre alignments in the Provadia region. The most active part is situated between the SouthMoesian subequatorial fault (N1) and NorthSupbalkan fault

(N2) – 81 events. 63 of them are concentrated in the Provadia valley, where the geodynamic influence of Hrabrovski (N4), Provadijski (N5), Padinski (N6) and Sultanski (N7) faults is observed. But this is namely the central part of the Provadia valley which is covered by the Mirovo salt deposit body. The nearby situated 18 December 2003' earthquake, with the M=4.4, is the strongest felt event since the beginning of the exploitation of this salt deposit body (Dimova et al., 2004). Because of the big depth of this event we can suppose that it isn't directly induced event. The very short aftershock sequence is an usual characteristic of the local tectonic earthquakes in the region, too.

The ordinary magnitude distribution of the earthquakes (Fig.3a) shows that the number of the events increases with the decrease of magnitude: for M > 4.0 it is 1, for M=3.5-3.9 - 3 for M=3.0-3.4 - 7, for M=2.5-2.9 - 20, for M=2.0-2.4 – 29, for M=1.5-1.9 - 56 events. The abrupt diminishing of the number of earthquakes in the next intervals determines also the registration power of the seismic stations network. In this way it can be supposed that the magnitude sample for levels with

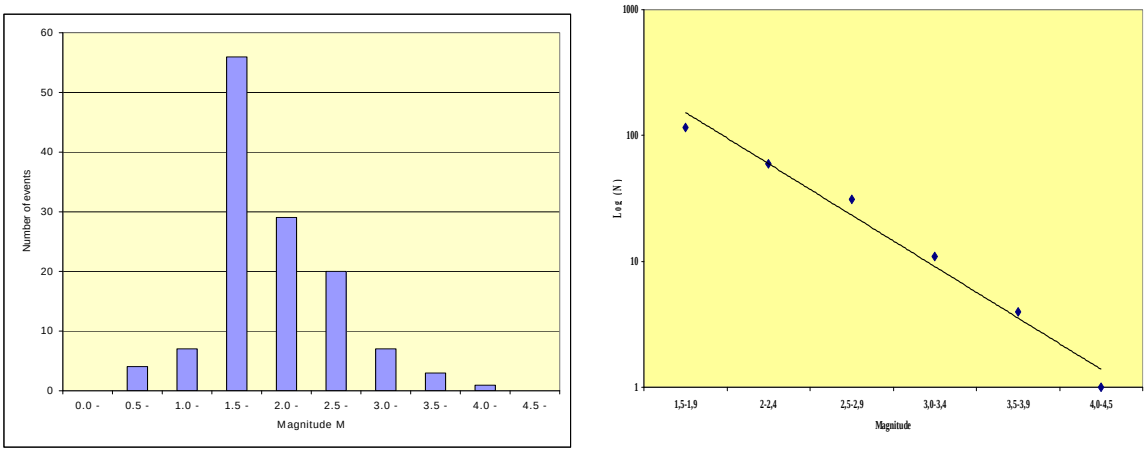


Fig.3. *Magnitude-frequency distributions of the earthquakes*

M > 1.5 is comparatively closer to the reality for the bigger part of the investigated territory. The coefficient *b* (or the slope) of the averaged straight line of the LogN-magnitude dependence (Fig.3b) is bigger in comparison with the standard dependence for North-East Bulgaria (for longer period and stronger events) which means that some "missing" of strong events is available.

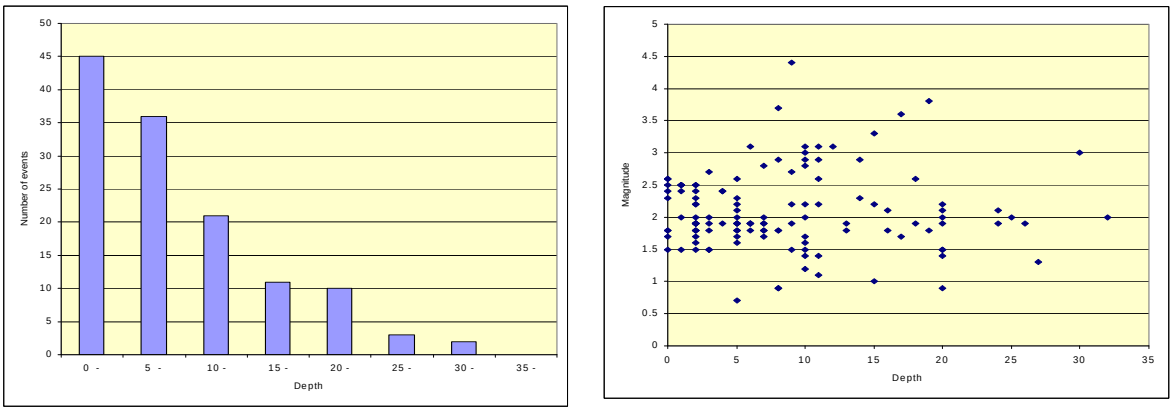


Fig.4. *Depth-frequency distributions of the earthquakes*

The ordinary depth distribution of the earthquakes shows that the majority of the events occur down to 20 km depth (Fig.4a). The slight decreasing of the number of the events with the increasing of depth is a natural phenomenon for the intraplate seismicity. The magnitude distribution of the events in depth (Fig.4b) allow to mark some differentiation of "depth floor" from 8 to 20 km depth – this is the depth interval of the strongest earthquakes. The 18 December 2003 earthquake, with the M=4.4, is the strongest felt event (Intensity VII) since the beginning of the exploitation of this salt deposit body. Because of the 9 km depth of this event we can suppose that it isn't directly induced event.

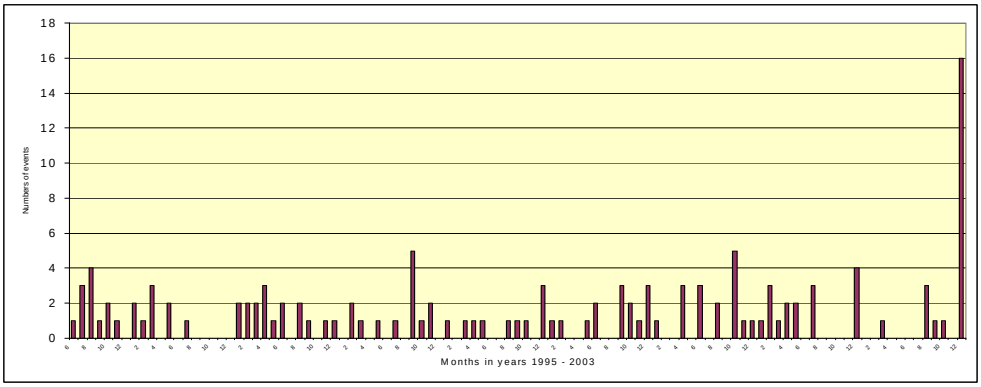


Fig.5. *Time distributions of the earthquakes*

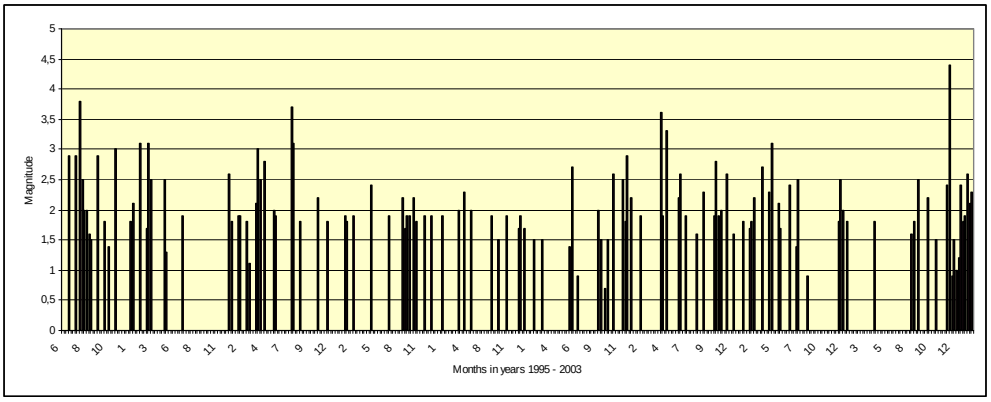


Fig.6. *Magnitude-time distributions of the earthquakes*

The time distribution of the earthquakes (Fig.5) does not allow to find out a quasi-periodic peculiarity of the seismicity. Some increase of the frequency of the earthquakes during 1997 and 2000 is not due to the aftershock sequences. The last strong frequency increasing is due to aftershocks of the strongest M=4.4 event on 18.12.2003. The magnitude – time distribution of the events (Fig.6) shows the specific decreasing of M in the time for the aftershock series of the earthquake with M=3.8 in the end of 1995. The very short aftershock sequence after the strongest event is an usual characteristic of the local tectonic earthquakes in the region, that is why we can not suppose that it is directly induced event.

As a conclusion we could generalize that:

The accuracy of determinations of epicenters of the earthquakes before the Provadia Local Seismic Network constructing is very low – even after the starting of NOTSSI operation many of epicenter calculations are with errors about 10 or more km ;

After the starting of Provadia LSN operation (1995), probably due to the higher accuracy of determinations of epicenters of the earthquakes, some clear expressed grouping of epicenters around the Mirovo salt body area is established – perhaps some influence of the salt body exploitation is observed;

The energetic level of the observed seismicity after 1995 is relatively weak (91% from the seismic events are microearthquakes (M<3.0)); the maximum magnitude is M=4.4 – the epicentre of this event is not far from the Mirovo salt body area;

The magnitude-frequency distribution of earthquakes shows that the earthquake catalogue is almost complete for events of M > 1.5. The slope of the averaging straight line of the recurrence relationship of events with magnitude M > 1.5 shows some prevalence of weak events;

The slight decreasing of the number of the events with the increasing of depth is a natural phenomenon for the intraplate seismicity. The biggest number of events in the depth interval 0-5 km might be associated with some influence of the salt body exploitation;

From the magnitude-depth and –time distributions is obtained that the depth interval of the strongest earthquakes is between 8 and 20 km and they are followed by classical (tectonic type) aftershock series. On these reasons we can suppose that the strongest earthquakes in Provadia region are not directly induced events;

The abrupt increasing of the number of felt earthquakes for the last 30 years and their hypicentral distribution around the Mirovo salt body does not allow to exclude the indirect influence of it's exploitation - like triggering of some tectonic seismic events, for example.

Acknowledgments: This work is partly supported by the grant ES 1512/2005 of the Ministry of Education and Science of Bulgaria.

References:

1. Bonchev E., V.I. Boune, L. Christoskov , J. Karagjuleva, V. Kostadinov, G.J. Reisner, Sn. Rizhikova, N.V., Shebalin, V.N. Sholpo and D. Sokerova. (1982): A method for com pilation of seismic zoning prognostic maps for the territory of Bulgaria. *GeologicaBalcanica*, 12.2, 3-48
2. Botev E., B. Babachkova, B. Dimitrov, S. Velichkova, I. Tzoncheva, K. Donkova, S. Dimi trova. (1993 – 2004): Preliminary data on the seismic events recorded by NOTSSI in January-June 1991 ... July-December 2003. *Bulg. Geophis. J.,* 16, 17, ... 30.
3. Botev E., S. Dimitrova, I. Tzoncheva. Seismicity patterns in the Provadia region recorded by NOTSSI before and after the Provadia Local Seismic Network construction. *Fourth National Conference with International Participation "Geophysics in economic activity, environment and cultural heritage investigations",* 4-5 Oct. 2004, Sofia. Book of Abstracts, publ. by Bulg. Geophys. Society, 2004, 56-57.
4. Christoskov L, D. Sokerova and Sn. Rizhikova. (1979). New catalogue of the earthquakes in the territory of Bulgaria and adjacent region for the period V century BC to XIX century, *Archives of the Geophysical Institute of BAS*, Sofia.
5. Dimova S., C. Christova, R. Glavcheva, M. Haralanov. A macroseismic survey in the epicentral zone of 17 December 2003 Provadia earthquake (Md 4.4), *Fourth National Conference with International Participation "Geophysics in economic activity, environment and cultural heritage investigations",* 4-5 Oct. 2004, Sofia, Book of Abstracts, publ. by Bulg. Geophys. Society, 2004, 72 – 74.
6. Grigorova E., D. Sokerova, L. Christoskov and Sn. Rizhikova. (1979): Catalogue of the earthquakes in the territory of Bulgaria for the period 1900-1977., *Archives of the Geophysical Institute of BAS*, Sofia.
7. Mihajlov D., S. Dineva, D. Sokerova, E. Botev, D. Ouzunov, L. Petrov, L. Dimitrova. Seismotectonic and seismological investigations for local seismological network constructing in the region of the Mirovsko salt body. *Third National Scientific-Practical Conference on Civil Protection,* 8-9 Dec. 1994, Sofia.
8. Solakov D. and S. Simeonova. /eds/ (1993): *Bulgaria catalogue of earthquakes 1981-1990.* Bulgarian Academy of Sciences, Geophysical Institute, Seismological department, Sofia.